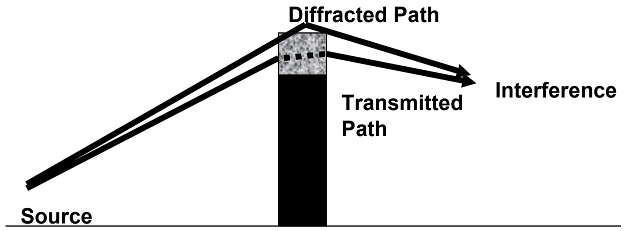
Performance of Roadside Sound Barriers with Sound Absorbing Edges



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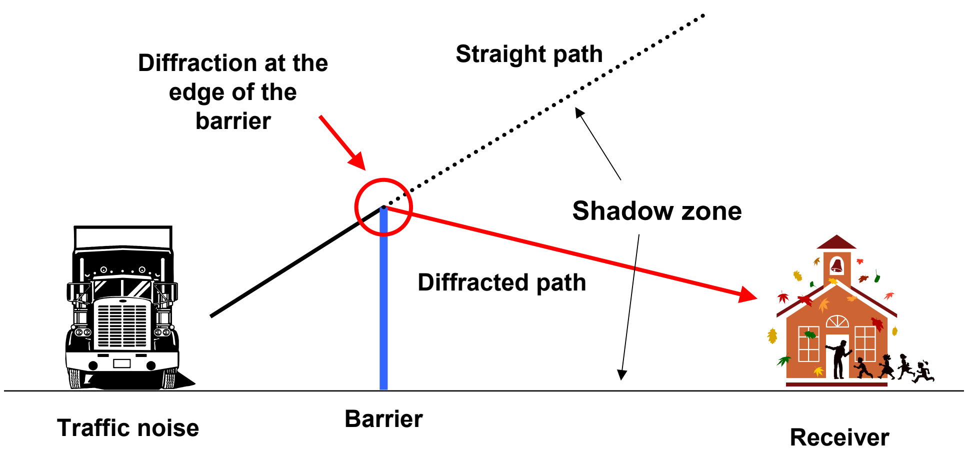
Co-Sponsored by:
Indiana Department of Transportation, Toll Road Division
Joint Transportation Research Program
Safe Quiet and Durable Highways

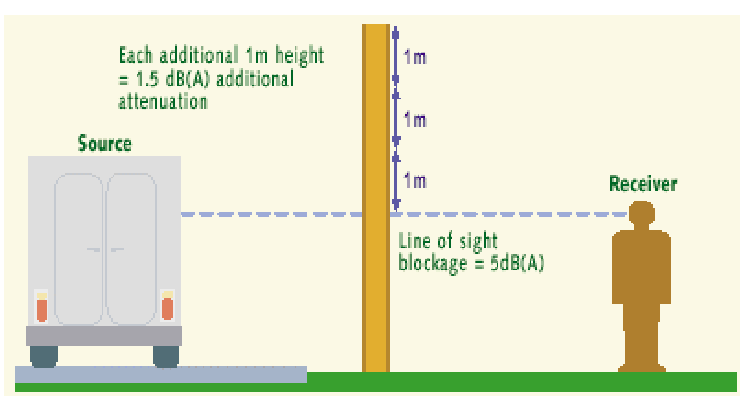
Sound Barriers



Example: Cantilevered barrier at Dordrecht, the Netherlands

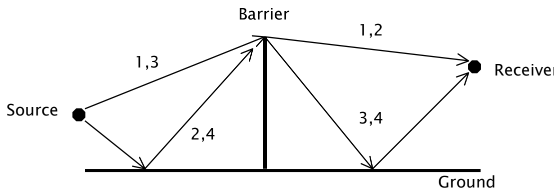
Environmental noise barrier, Benz Koreten & Colin English, E & FN Spon,1999.

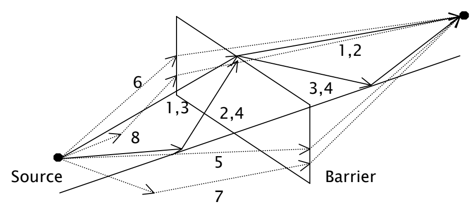
Barrier Effectiveness



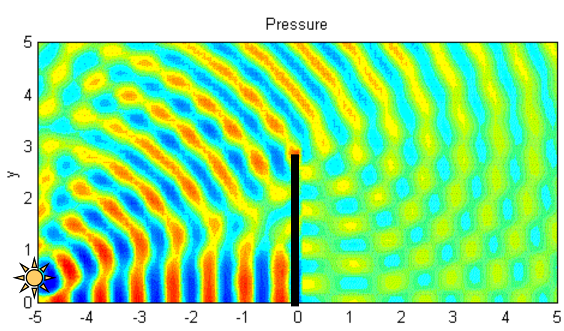
from www.fhwa.dot.gov

Barrier Problem

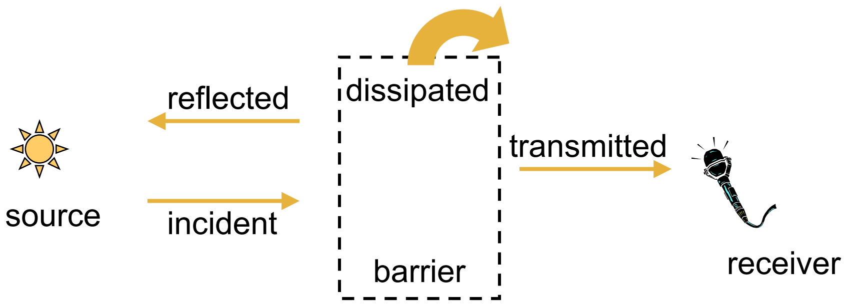




Numerical Simulation
Rigid Barrier with Reflecting Ground



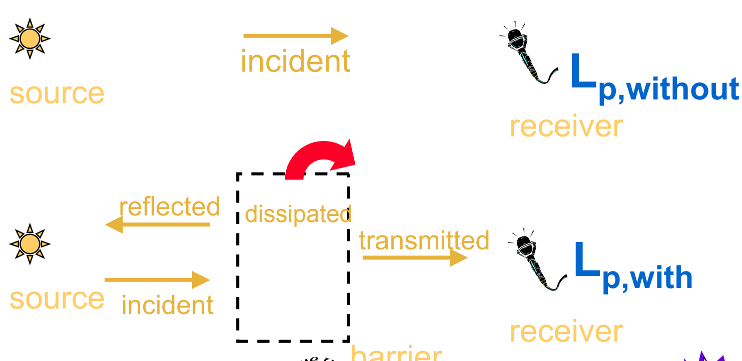
Metrics of Barrier Performance



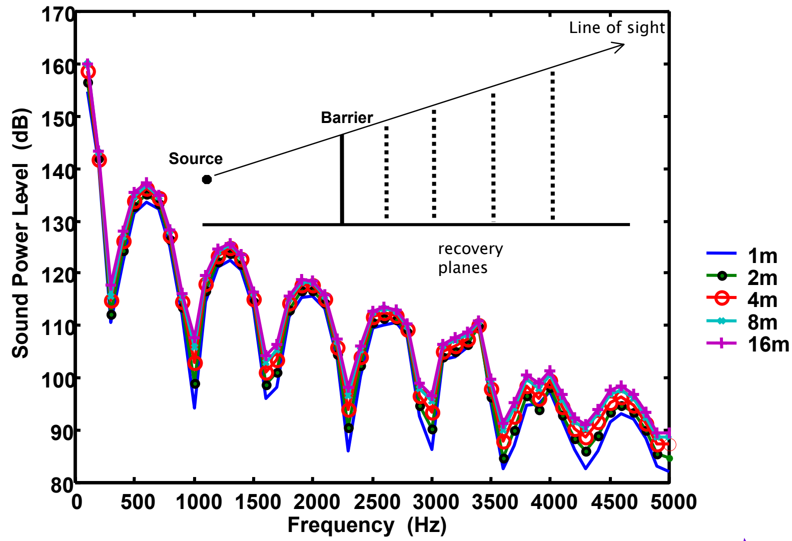
- *Noise Reduction (NR)*
- *Insertion Loss (IL)*
- *Transmission Loss (TL)*

Insertion Loss

- *Difference between the SPL's at the receiver without and with barrier*
- $$IL = L_{p,without} - L_{p,with}$$



Sound Power Crossing Recovery Planes



Motivation

- ***Highway sound barriers often used to solve community noise problems***
- ***Barriers expensive (approx \$20/ft^2 of barrier installed)***
- ***Barrier performance and cost directly proportional to height***
- ***Are there ways to enhance performance, reduce costs?***

Objectives

- *Investigate relatively novel barrier concepts:*
  - **non-uniform edge geometries**
  - **absorbing materials**
- *Develop and validate boundary element method for sound barrier performance predictions*
  - *Design optimization*
- *Investigate new metrics to compare performance of different barrier concepts*

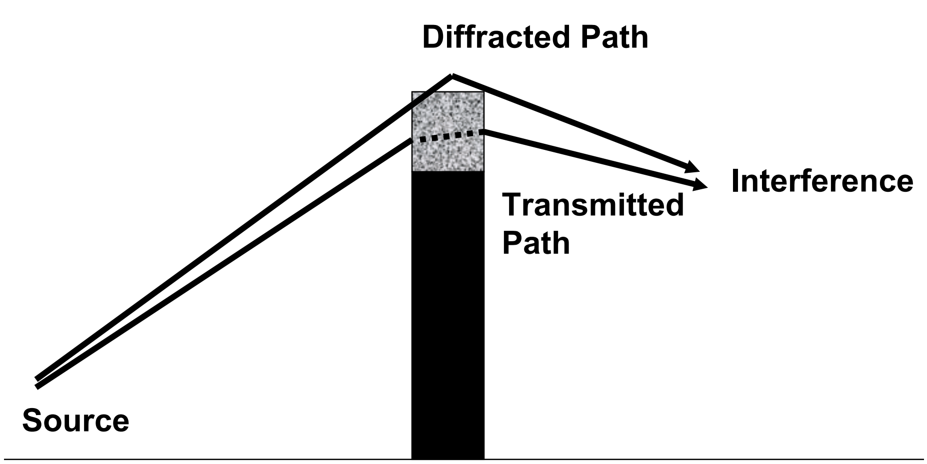
Rationale

- *Most existing models approximate: based on geometrical acoustics (“ray theory”)*
  - *or semi-empirical*
- *Model often not amenable to complex barrier shapes*
- *Comparing barrier at one single location introduces a bias*
- *Novel concepts and FEM models not new*
  - *work still needed for assessment*

Methods

- *Laboratory Experiments*
  - small barrier models in anechoic room
  - random and impulsive input signals
  - time windowing eliminate effects of spurious reflection
  - Fourier methods to calculate TF's
- *Boundary Element Predictions*
  - LMS Sysnoise (MSC Patran pre-processor)
  - Indirect variational method
- *Field Measurements*
  - Full scale tests on actual barrier

Novel Concept: Sound Absorbing Barrier Top

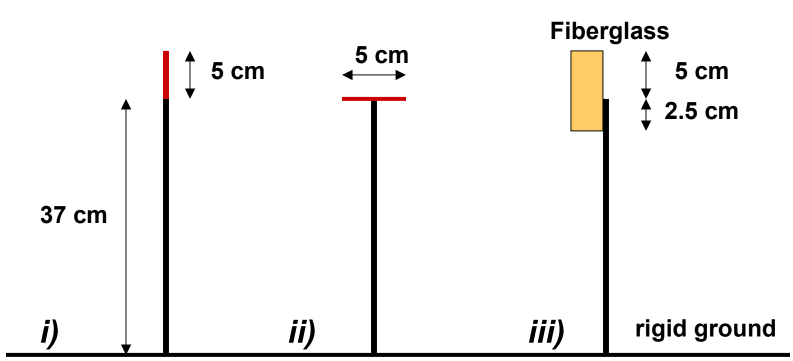


Laboratory Experiments

- **Scaled Model (1:10)**
- **Initial Assessment of Novel Concept Performance**

Barrier configurations

- **i) *Rigid linear extension***
- **ii) *Rigid T-shape***
- **iii) *Sound absorptive treatment (soft top)***



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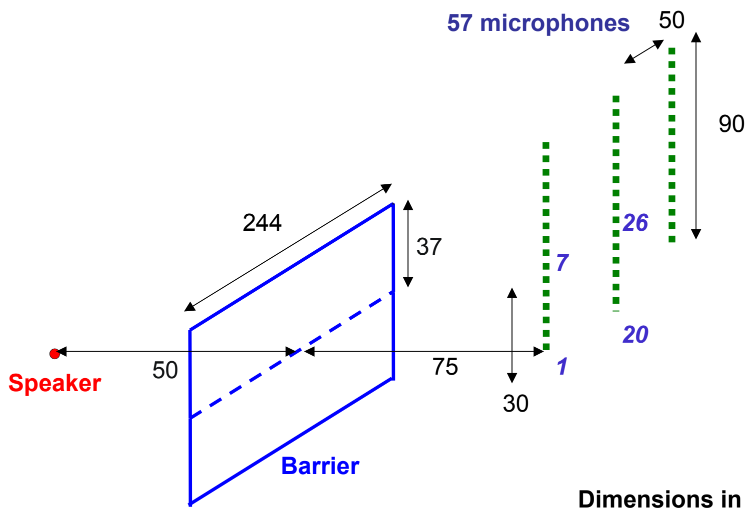
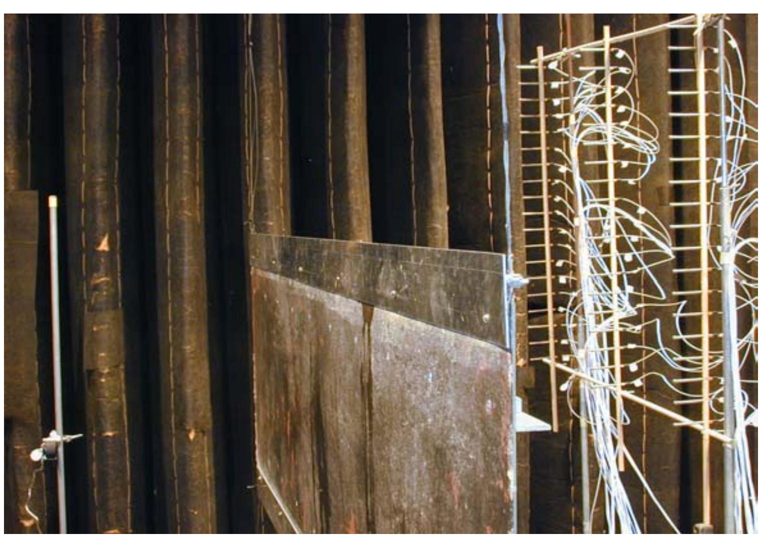
Microphone Locations

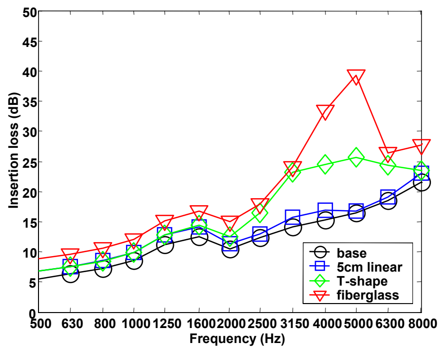


Dimensions in cm

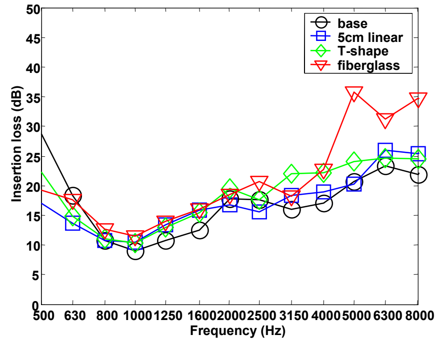
Experimental setup



Local insertion loss comparisons



location 20



location 26

- **Insertion Loss with Sound Absorbing Top Better**
- **Varies with Receiver Location**

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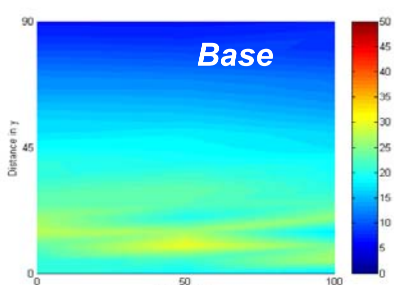
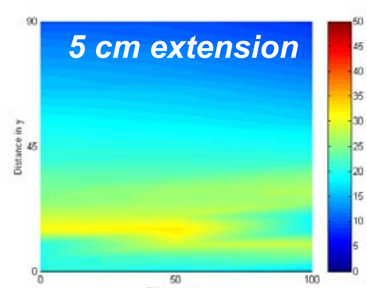
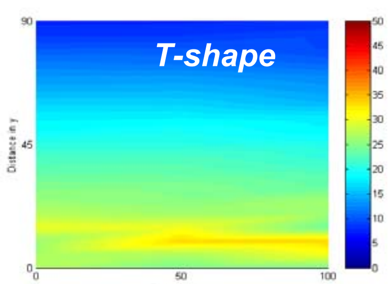
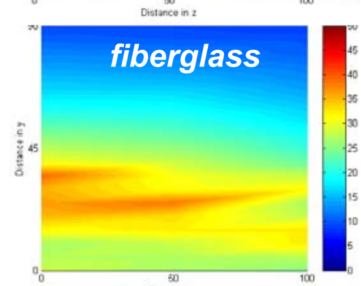
Insertion loss distribution at6300 Hz (1/3 octave band)









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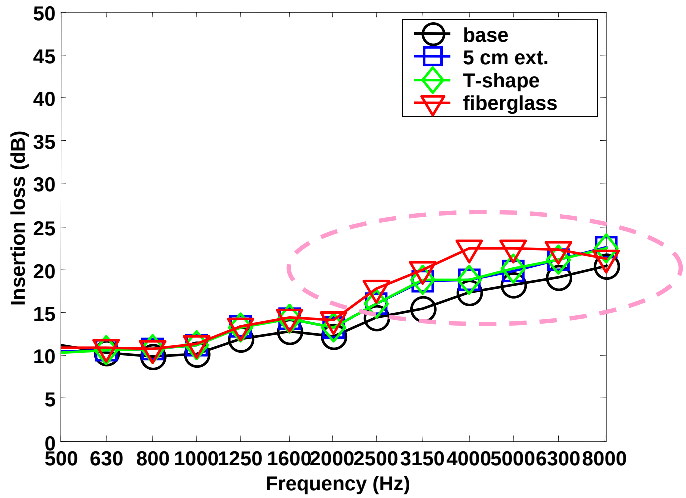
Spatially-averaged insertion loss



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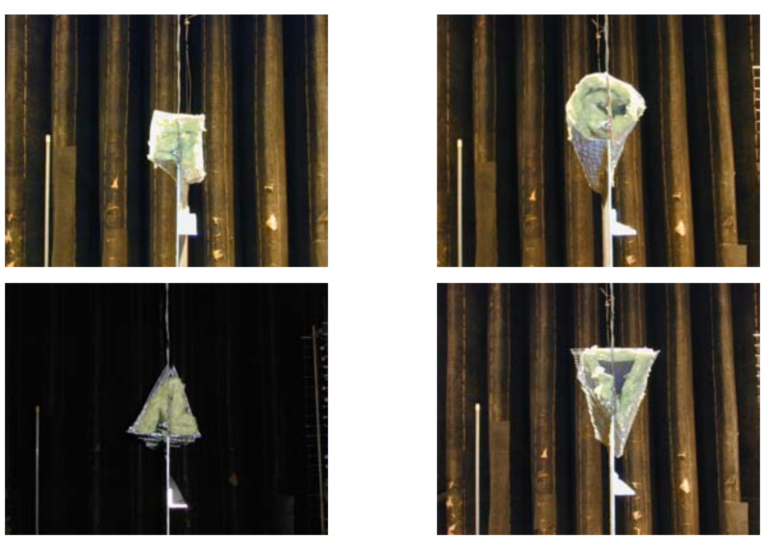
Shape Optimization



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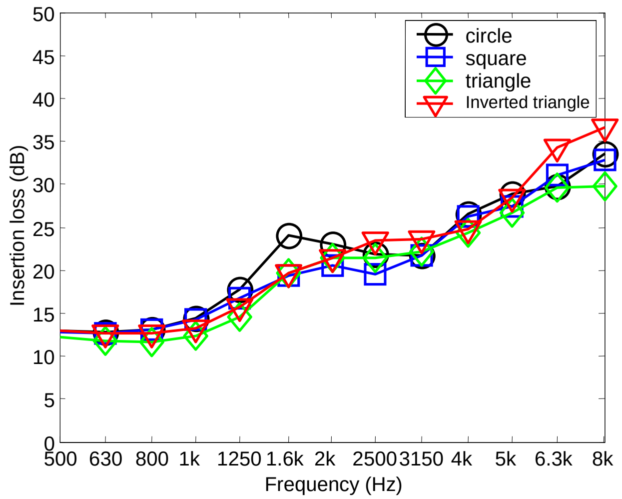
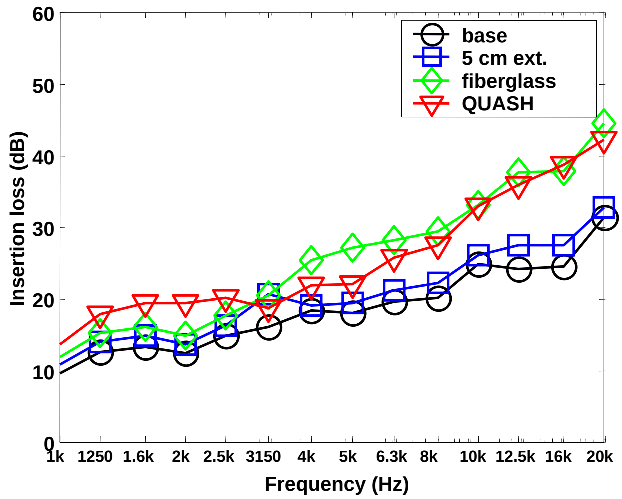
Space-averaged insertion loss



QUASH

- **closed-cell foam made of polyolefin**
- **good sound absorption at low and medium frequencies**
- **does not absorb water as much as conventional materials like fibers, polyurethane foams, and melamine foams**
- **UV tolerant**
- **Performance comparable to that of Fiberglas, depending on frequency**

Space-averaged insertion loss



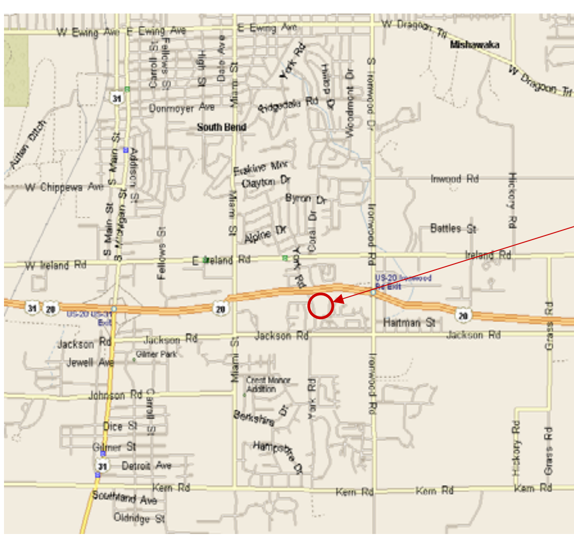
Conclusion from Scaled Model Studies

- The Addition of Sound Absorbing Materials on Barrier Top Improves Performance
- Advantage over other design concepts
- Shape of the “soft top” has an effect on the barrier performance
- Circular shape optimal
- Use of QUASH promising for outdoor implementation

On-site measurements

- **Preliminary measurements at three locations**
- **Measurement site: east of York Rd. and on the south side of bypass in South Bend, IN**
- **Chosen for relatively level, grassy terrain, distant from residential and commercial buildings**
- **Measurements were done before and after the absorptive material installation to evaluate the effectiveness of add-on device**

Map of the measurement site



Community park

- Fairly large open space
- Grass covered
- Nearby Residents
- Existing barrier gaps

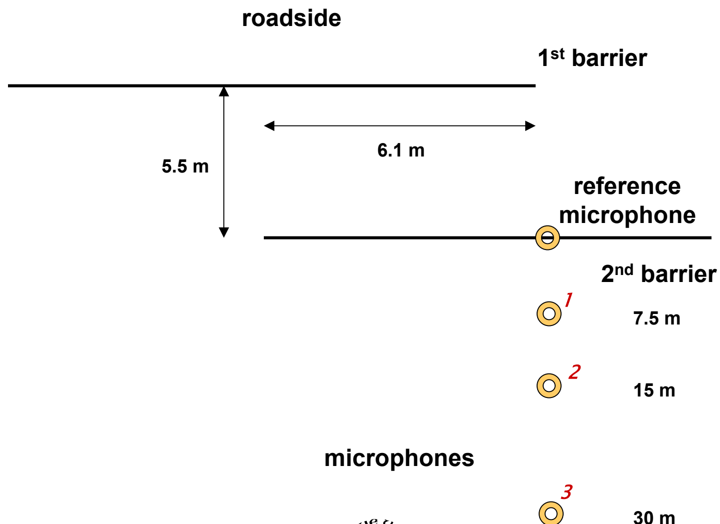
Instrumentation

- Four Bruel & Kjaer 12.6 cm (½ in.) microphones (Type 4089 and 4090)
- Bruel & Kjaer Pulse analyzer (1 hour one-third octave band measurements)
- Davis Weather Wizard III weather station (direction and speed of the wind and temperature)
- Traffic classifier (numbers and average speeds of cars, mid-size and heavy trucks over one hour)

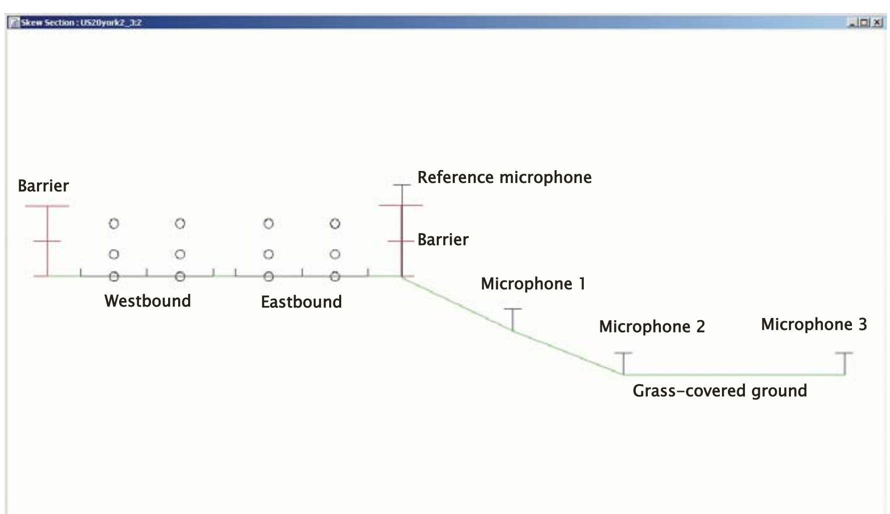
TNM simulations

- TNM: “Traffic Noise Model”, available from the Volpe Center, commissioned by FHWA
- Goal to approximate SPL from existing barrier to assess benefits from barrier attachments
- Geometry of simulation input from road plan giving grade and curvature, as well as dimensions of wall
- Traffic density data obtained using a traffic classifier

Measurement locations (top view)



TNM Model



Measured traffic data (8/31/02)

	Type of vehicles	1 PM – 2 PM	2 PM – 3 PM
E.	Cars	789	780
		95.6 kmph	95.6 kmph
	Mid-sized trucks	16	17
		88.8 kmph	90.0 kmph
	Heavy trucks	44	28
		95.0 kmph	90.3 kmph
W.	Cars	944	899
		99.6 kmph	99.8 kmph
	Mid-sized trucks	30	17
		95.3 kmph	98.0 kmph
	Heavy trucks	57	47
		90.0 kmph	96.6 kmph

A-weighted overall sound pressure level

	1 PM – 2 PM		2 PM – 3 PM	
	Measured	TNM	Measured	TNM
Reference Microphone	78.3 dBA	75.8 dBA	78.8 dBA	75.3 dBA
Microphone 1 (7.5 m)	56.6 dBA	55.9 dBA	57.7 dBA	55.2 dBA
Microphone 2 (15 m)	55.1 dBA	55.7 dBA	56.7 dBA	55.0 dBA
Microphone 3 (30 m)	56.3 dBA	55.5 dBA	57.8 dBA	54.8 dBA

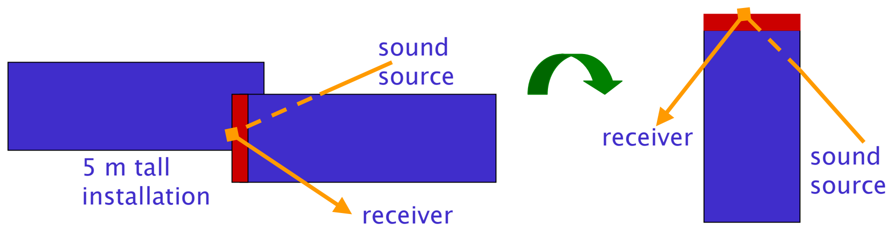
- **TNM under-predicts SPL by 1 dB to 3 dB**
- **complex terrain, atmospheric factors possible reasons**

Treatment of barrier gap

- *Horizontal edge treatment (initial plan)*

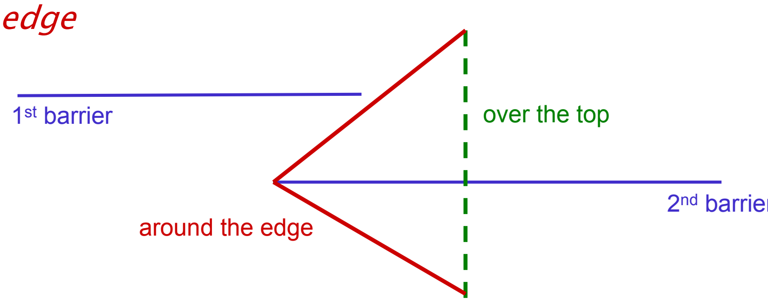
Requiring at least 100 m long treatment for the receiver at 25 m

- *Vertical edge treatment (final plan)*



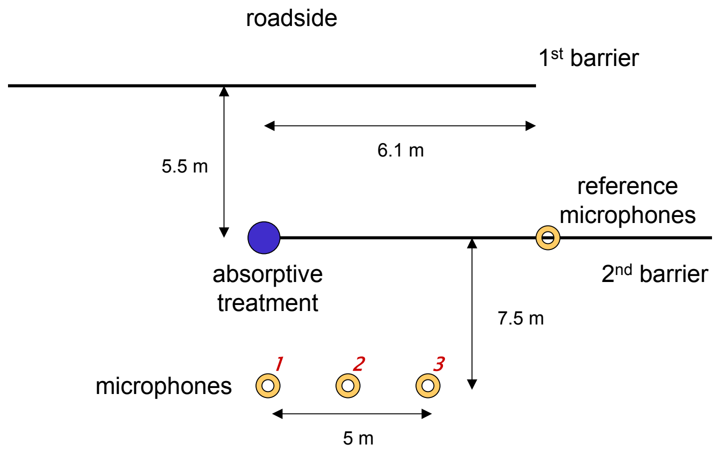
Receiver location selection

- *Two diffraction paths: over the top and around the edge*



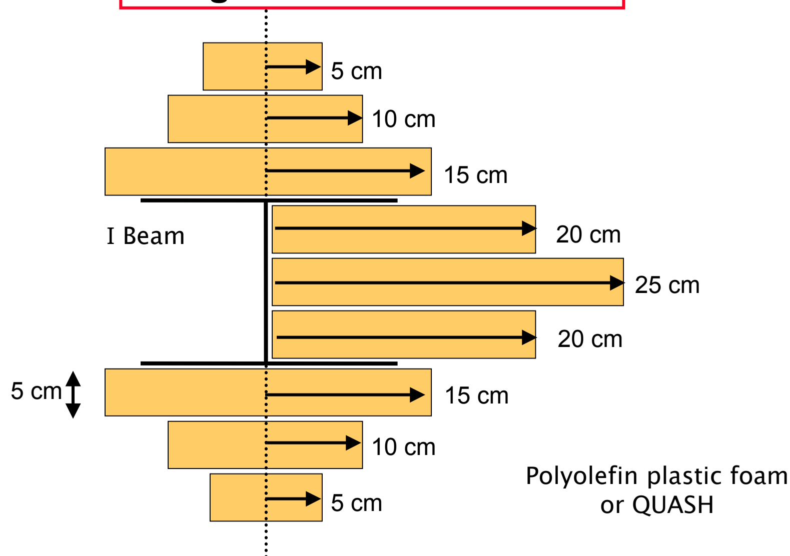
- *Receiver locations chosen where diffraction around vertical edge dominates*

Measurement locations



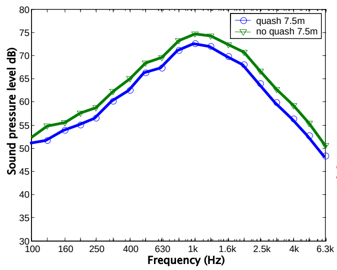
Picture of the Site

Design of add-on treatment

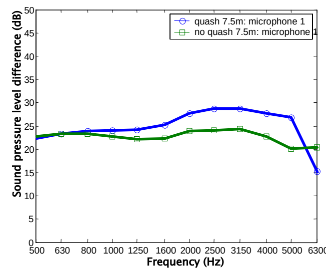


Picture of Modified Barrier

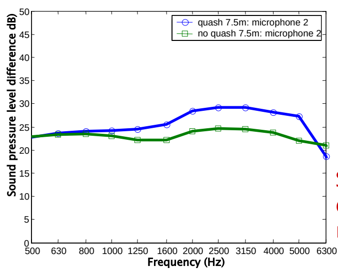
Measurement results



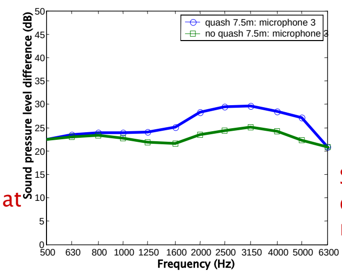
SPL at reference mic



SPL difference at mic 1

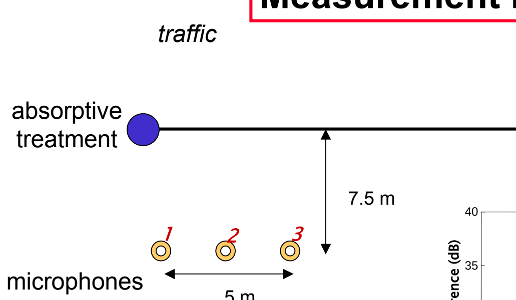


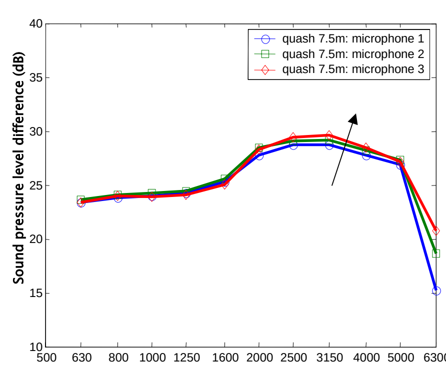
SPL difference at mic 2



SPL difference at mic 3

Measurement results



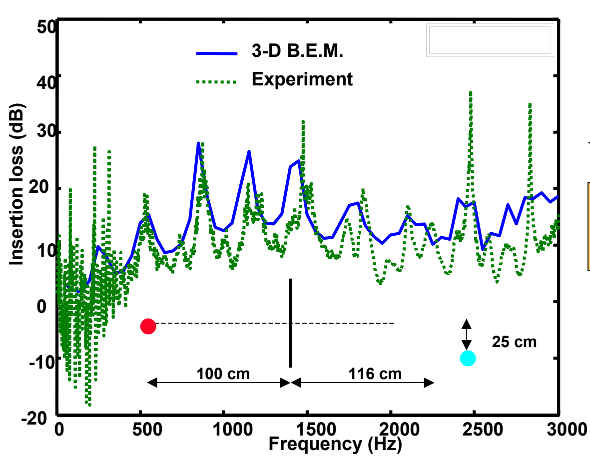


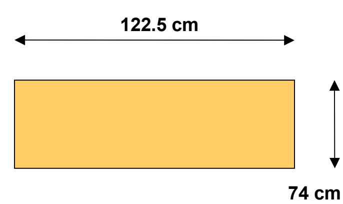
Absorptive treatment is more effective deeper in shadow zone

Summary of Road Tests

- On-site preliminary measurements were performed
- The sound absorbing edge concept was effective at high frequencies
- A larger installation is required for more rigorous investigation

BEM Model Validation: Straight rectangular barrier



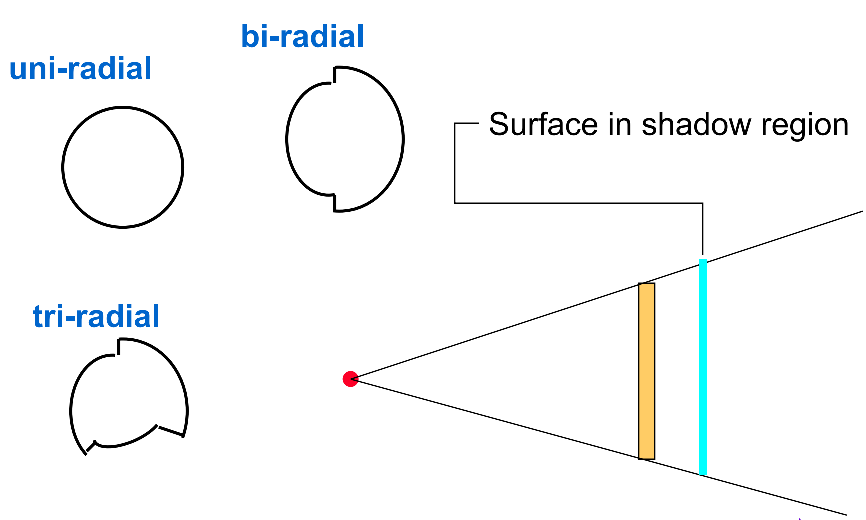


Experimental validation

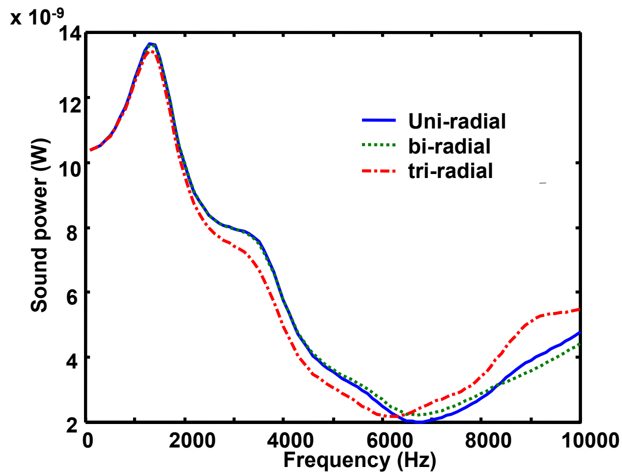
- *BEM models accurate*
  – more accurate than diffraction based models

- *Detailed experiments challenging even in controlled laboratory conditions, with*
  – known input signals
  – minimal environmental effects
  – high precision instrumentation
  – lots of post-processing

Effects of Complex Geometries



Effects of Complex Shapes: Sound power over the shadow region



Conclusions

- *BEM models accurate*
  - allow design optimization for complex designs
- *Irregular top shapes don't affect sound power in shadow region*
- *T-shaped barriers moderately better than straight barriers (for equivalent quantities of material)*
- *Benefits of absorbing material on barrier top verified in laboratory and on-site !*
  - no models yet
  - further work needed for concept to be implementation-ready